1975

Effects of companionate crops and their aqueous extracts on the population dynamics of insects injurious to potato plants.

Alfred Jean Sorensen
University of Massachusetts Amherst

EFFECTS OF COMPANIONATE CROPS AND THEIR AQUEOUS EXTRACTS ON THE POPULATION DYNAMICS OF INSECTS INJURIOUS TO POTATO PLANTS

A Thesis Presented

By

Alfred Jean Sorensen

Submitted to the Graduate School of the
University of Massachusetts in partial
fulfillment of the requirements for the degree of

MASTER OF SCIENCE

June 1974

Entomology

EFFECTS OF COMPANIONATE CROPS AND THEIR AQUEOUS EXTRACTS ON THE POPULATION DYNAMICS OF INSECTS INJURIOUS TO POTATO PLANTS

A Thesis

By

Alfred Jean Sorensen

Approved as to style and content by:

T. M. Peters, Chairman

John H. Lilly, Member

Adrian G. Gentile, Member

T. M. Peters, Department Head
Department of Entomology

June, 1974

ACKNOWLEDGMENTS

I wish to express my appreciation to my advisor, Dr. T. M. Peters, whose guidance, advice, encouragement and editorial suggestions were invaluable in the completion of this work.

I also wish to extend my sincere gratitude to Dr. John H. Lilly for his advice and critical review of the manuscript.

I extend particular thanks to Dr. Adrian G. Gentile for his efforts in reviewing this thesis and serving as a member on my graduate committee.

My thanks and appreciation go to Dr. Richard A. Damon, Jr. whose guidance and assistance with the statistical aspects of this work was of paramount importance.

I reserve with devotion, special thanks and appreciation to my wife Eileen whose patience, understanding and encouragement were immense and unfailing throughout the course of this graduate program. Her unenviable role as typist is greatly appreciated.

This thesis is in two parts. The first part which consists of the ABSTRACT, INTRODUCTION, METHODS AND MATERIALS, RESULTS AND DISCUSSION, CONCLUSIONS and LITERATURE CITED is a manuscript which will be submitted to the Journal of Economic Entomology. The second part of the thesis (APPENDIX) which will not be published contains a complete LITERATURE REVIEW, ADDITIONAL RESULTS AND DISCUSSION and a SUPPLEMENTARY LITERATURE CITED section which are pertinent to the entire thesis.

TABLE OF CONTENTS

Page

MANUSCRIPT FOR PUBLICATION
- ABSTRACT vi
- INTRODUCTION 1
- METHODS AND MATERIALS 4
  - Field experiments 4
  - Greenhouse experiments 10
- RESULTS AND DISCUSSION 14
  - Field experiment - treatments 14
  - Greenhouse experiments - treatments 21
- CONCLUSIONS 23
- LITERATURE CITED 26

APPENDIX
- LITERATURE REVIEW 30
  - Insects harmful to potatoes 30
  - Control of potato insects 30
    - Chemical control. 30
    - Non-chemical control 32
  - Organic gardening 33
  - Intercropping considerations 35
  - Ecological considerations 43
- ADDITIONAL RESULTS AND DISCUSSION 46
  - Field experiment - blocks 46
  - Greenhouse experiments - blocks 49
  - Randomized block design for field experiment (Fig. 3) 50
  - Field experiment 51
    - Analysis of variance 51
  - Field experiment - treatments 62
    - General statistics. 62
    - Duncan's new multiple range test at .05 65
    - Duncan's new multiple range test at .01 71
  - Field experiment - blocks 77
    - Duncan's new multiple range test at .05 77
    - Duncan's new multiple range test at .01 83
  - Greenhouse experiments 87
    - Analysis of variance 87
  - Greenhouse experiments - blocks 89
    - Duncan's new multiple range test at .05 89
- SUPPLEMENTARY LITERATURE CITED 90

ABSTRACT

Quantitative measurements of insect counts, plant damage and tuber weights taken on potato plants were used to determine the effectiveness of certain plants which have been reported to have a repellent effect on insects. Fewer insects and less plant damage were observed on potato plants in the early part of the growing season when they were surrounded by marigolds or green beans. Potato plants surrounded by garlic had greater numbers of insects but sustained little damage early in the growing season. Marigolds and green beans exerted a repellent effect on the insects whereas garlic had a feeding deterrent effect. Although potato plants were initially protected from damage by these companionate plants heavy damage did occur later in the growing season. Tubers harvested at the end of the growing season showed greatest yield in the chemical control. Tuber weights in the chemical control were significantly greater than other treatments at the 1% level of significance. Tuber weights in treatments other than the chemical control showed no significant differences.

An aqueous spray made from an extract of the companionate plants was ineffective in protecting potato plants during any part of the growing season.

INTRODUCTION

Because the use of pesticides is being increasingly restricted, and also because insects have the capacity to develop resistance to pesticides, it is imperative that we attempt to develop new methods of protecting crops from phytophagous insects. In order to provide such crop protection we should have a more complete understanding of insect-plant relationships, especially the chemical ecology of plants and insects, because this area of research holds great promise for insect control.

Current agronomic practice is based on monocultural techniques. These techniques have increased the ease of crop production but have magnified pest problems as explained by the "Resource Concentration Hypothesis." According to this hypothesis, herbivores are more likely to find and remain on hosts that are growing in dense or nearly pure stands, and the most specialized species frequently attain higher relative densities in simple environments which they are capable of utilizing. As a result, biomass tends to become concentrated in a few species, causing a decrease in the diversity of herbivores in pure stands (Root, 1973). Monocultures are also colonized more rapidly and exhibit greater feeding damage than diverse stands in which three crop plants are grown together (Tahvanainen and Root, 1972). Species diversity of fauna and flora within a habitat is an important factor in stabilizing the habitat and preventing population outbreaks in communities (Pimentel, 1961; Dempster, 1969; Smith, 1969). However, diversity of habitat outside the crop may not add to the stability of crop pest populations (Pollard, 1971).

In an attempt to protect crops without the use of synthetic insecticides, organic gardners have increased their garden's diversity by intercropping with certain plants which have been reported to be "repellent" to insects. Intercropping of this type is one form of "companionate planting." Another method of utilizing a plant's "repellency" to protect crops is the use of "repellent" plant extracts sprayed on the crop. However, popular reports on the use of companionate plantings and plant extract sprays as plant protection methods lack objective experimental supporting data (Rodale, 1969, 1971; Merrill, 1972; Philbrick and Gregg, 1973). Consequently, there is a real need for research in this area to either prove or disprove the claims made in these reports.

Among the species that have been reported by the above authors to have a generally repellent effect on insects are green beans, marigolds and garlic. To determine if these plants have any effect on insects injurious to potato plants a study was designed to test the following null hypothesis: Marigolds, garlic and green beans do not affect the population dynamics of the Colorado potato beetle (CPB) *Leptinotarsa decemlineata* (Say) or the potato flea beetle (PFB) *Epitrix cucumeris* (Harris), on potato plants either when grown in close proximity with potato plants (the target crop) or when their extracts are sprayed onto potato plants.

METHODS AND MATERIALS

Field Experiments

Field experiments were conducted at the University of Massachusetts South Deerfield farm on land in which vegetable crops had not been grown for at least ten years. A total of 72 plots consisting of 6 replications of 12 different treatments were planted in a randomized block design. Each treatment consisted of 6 Irish Cobbler potato plants designated as the target plants. In 5 treatments companionate plants (marigolds, green beans, garlic, potatoes and plastic asparagus ferns) were planted surrounding the 4 middle target plants (Fig. 1A). In 4 of the 7 remaining treatments the target potato plants were sprayed with aqueous extracts of the plants (marigolds, green beans, garlic and potatoes) used in the companionate treatments. Agway multi-purpose fruit spray containing captan (15.0% by wt.), malathion (7.5% by wt.) and methoxyclor (15.0% by wt.) used at 1 lb/12.5 gals. and a distilled water supply spray complete the spray treatments. One remaining treatment consisted of potato plants alone (Fig. 1B). See Table 1 for a complete list of treatments.

Aqueous extract sprays were made by using entire companionate plants with distilled water as a diluent. Each group of plants (marigolds, garlic, beans or potatoes)

Fig. 1.

Treatment design: companionate plantings A, all other treatments B. ○ = Irish cobbler potatoes (target plants), △ = companionate plants.

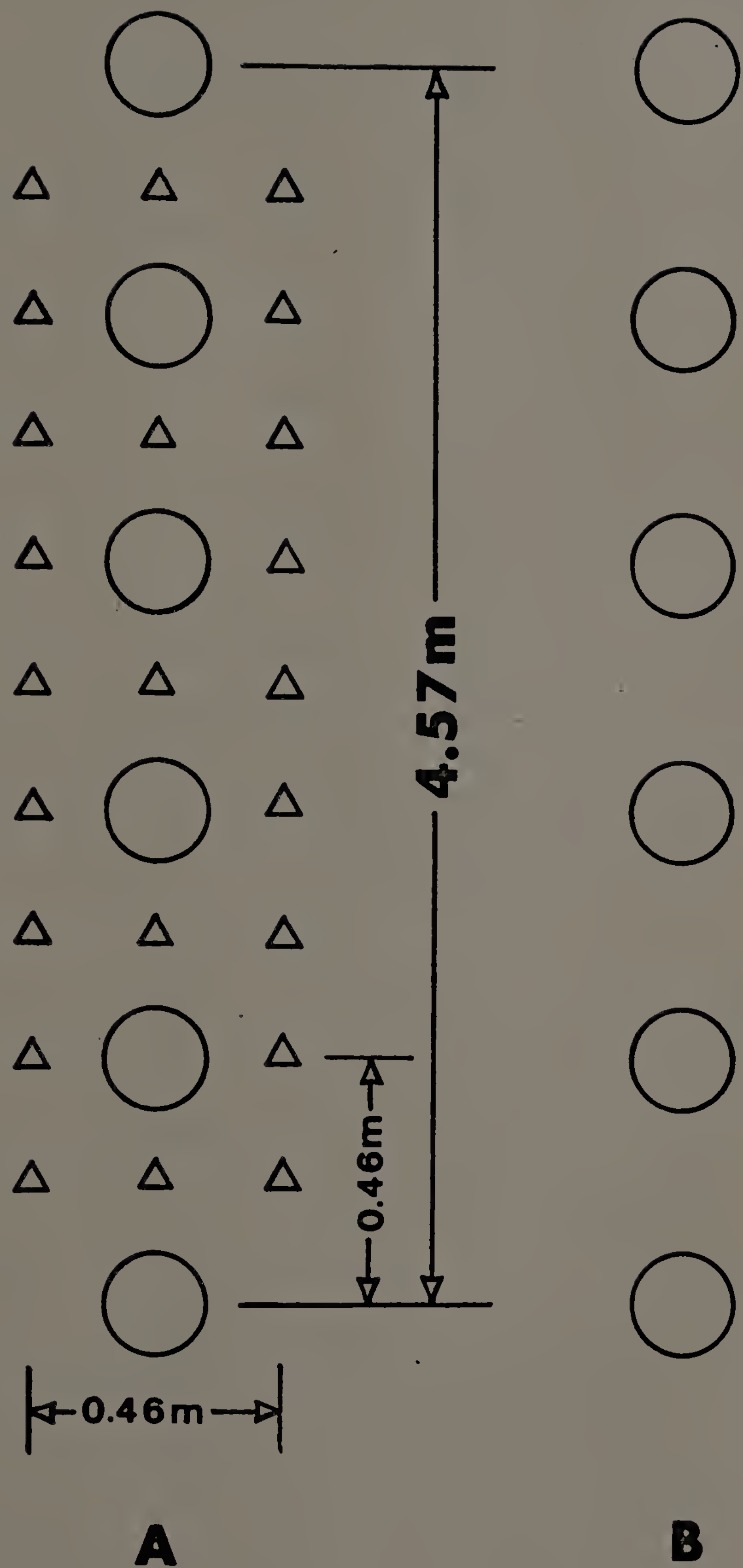

4.57m
0.46m
0.46m
A
B

Table 1. Field Treatments

Companionate Agway Provider beans
Companionate marigolds (*Tagetes* sp.)
Companionate garlic (*Allium sativum*, L.)
Companionate plastic ferns
Companionate Irish Cobbler potatoes
Aqueous spray of bean extract
Aqueous spray of marigold extract
Aqueous spray of garlic extract
Aqueous spray of potato extract
Agway multi-purpose fruit spray
Distilled water spray
Untreated control

was first weighed and then ground up in a Waring Blendor (Model 702B) at "Hi" speed. The amount of distilled water added to each group of plants varied according to the degree of viscosity of the extract. Marigolds, beans and potatoes had 6 times as much water added to them as the weights of the plants. Garlic had 10 times as much water added to it. Ground garlic required a greater amount of water because the mixture was too viscous to spray when only 6 times as much water as the weight of the plant was added to it. The blended mixture was then passed through a series of filters; the first filter being #8 mesh screen. The second filter was #15 mesh screen and the last filter was bolting cloth. Particles in the fluid passing through the bolting cloth were small enough to pass through a sprayer (Hudson Favorite, No. 9) without clogging the nozzle. Spraying operations were conducted at weekly intervals, weather permitting (Table 2).

Prior to planting, each treatment was composted with approximately 0.14 cu. m. of compost which was roto-tilled into the top 15-20 cm. of soil. The compost was made using the 14 day method developed at the University of California (Rodale, 1971). Fresh stable manure and rotted hay were shredded using an Ariens Shredder (Model Number 928001). One-hundred sixty pounds of lime was added to the compost pile. The compost was then moistened

TABLE 2. Schedule of plant sprayings and assessments.

SPRAY INTERVAL (DAYS)	DATE SPRAYED	DATE ASSESSED	ASSESSMENT OF INSECT DAMAGE AND PRESENCE
	26 JUNE	-----	NO ASSESSMENT (RAIN)
6			
	2 JULY	2 JULY	PFB DAMAGE
9		3 JULY	CPB LARVAE CPB ADULTS
	11 JULY	12 JULY	PLANT DAMAGE CPB LARVAE* CPB ADULTS
7			
	18 JULY	19 JULY	CPB LARVAE CPB ADULTS
7			
		20 JULY	PLANT DAMAGE
	25 JULY	26 JULY	CPB LARVAE CPB ADULTS
7		31 JULY	PLANT DAMAGE
	1 AUGUST	2 AUGUST	NO ASSESSMENT (RAIN)
		3 AUGUST	CPB LARVAE CPB ADULTS
7			
	8 AUGUST	9 AUGUST	CPB LARVAE CPB ADULTS
		20 AUGUST	TUBER WEIGHTS

* SAMPLE COUNT
PFB = Potato Flea Beetle
CPB = Colorado Potato Beetle

with water, covered with clear 4 ml. plastic and turned over on the fourth, eighth and eleventh day after shredding. On the fifteenth day the compost pile had cooled down and was ready for use. Companionate plants were planted first. Bean seeds were planted 5 cm. apart, garlic and marigolds transplanted from the greenhouse were planted 13 cm. apart and potato seed pieces were planted 45 cm. apart. One week later the potatoes used as target plants were planted along with the border row of potatoes and the plastic asparagus ferns were placed in the ground with cladophylls touching. Companionate plastic asparagus ferns were utilized to determine if a physical barrier resembling a plant had any effect on the insect population on potatoes. Missing target or companionate potato plants were replanted.

Those treatments designated as spray treatments were first sprayed on the 27th day after planting. Target plants were sprayed to the point of run-off. A plastic shield was used to protect other treatments from drift. Only the 4 middle target plants were used to gather data for the experiment. They were used because they had competition from target crops on both sides of them (see Fig. 1), whereas the end target plants did not and would tend to grow larger. In the companionate plantings they were the only plants to be completely surrounded by companionate plants.

Insect counts were taken between 9 A.M. and 5 P.M. on the day after spraying, if weather conditions were favorable. No counts were taken more than two days after spraying. All insect counts were total counts with the exception of one CPB larvae count taken on 12 July. PFB damage was assessed by removing the lowest 4 leaves from each of the target plants and counting the number of holes caused by the PFB. The number of holes from each plant was then divided by the number of leaflets from that plant to obtain an average number of holes/leaflet/plant. The CPB larvae sample was taken by counting all the larvae on a single branch, chosen at random, from each of the target plants.

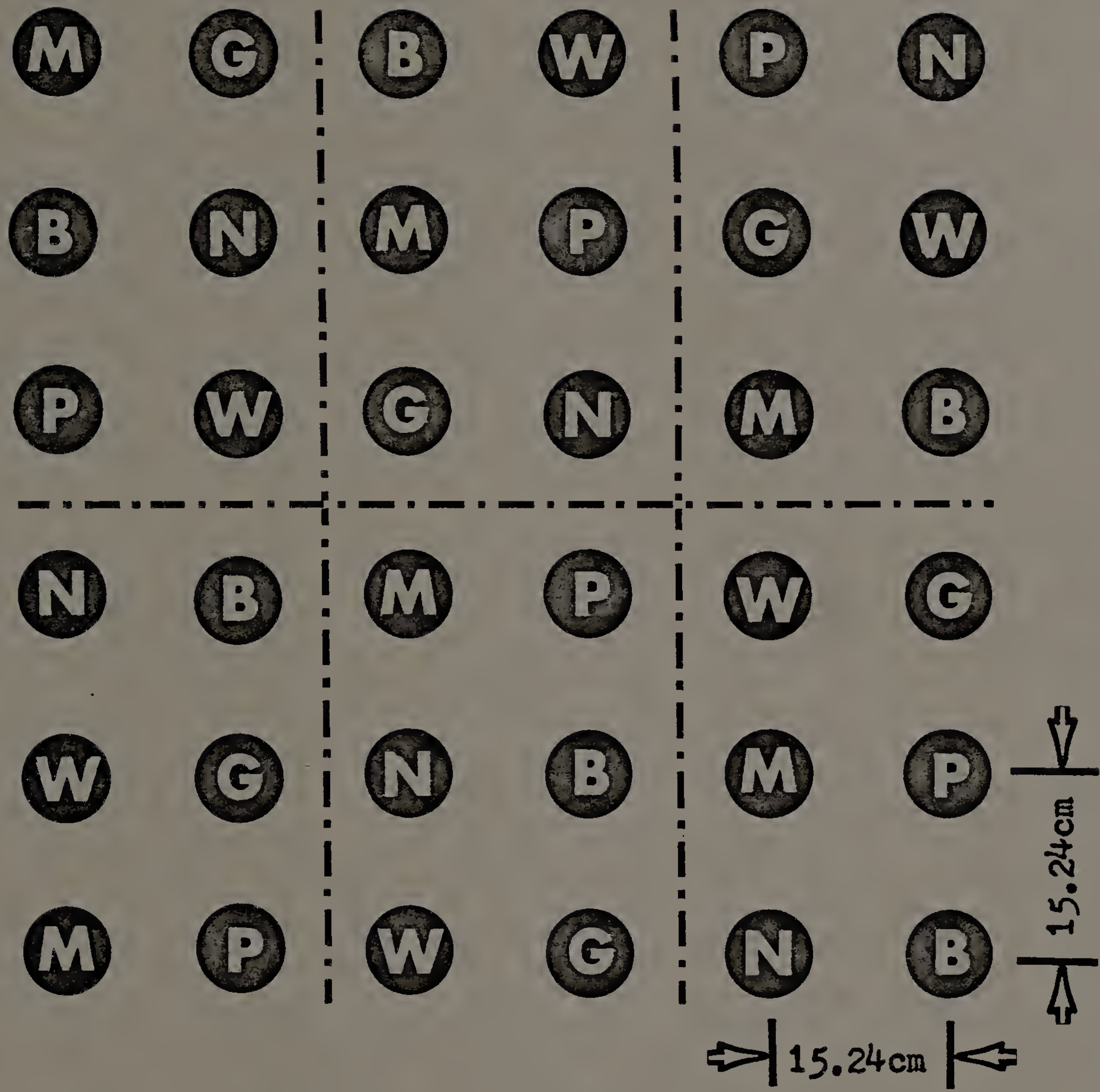
Damage assessments were taken 3 times throughout the growing period and the tubers were weighed at the end of the season (Table 2). Damage was assessed by having two individuals estimate the percentage of the target plant that had been consumed. If the assessments were within 10 percentage points of each other an average was taken. If the differences were greater, the plant damage was discussed and a mutual agreement was reached. Most obvious damage was due to the CPB while a much smaller percentage was caused by the PFB.

Greenhouse Experiments

A randomized plot design of six blocks with six treatments was used to test the repellancy of potato plants covered with plant extracts (Fig. 2). Thirty-six glass vials (1.8 cm ID x 7.0 cm) were set in soil in a screened cage (0.96 m. x 0.96 m. x 0.93 m.) within a greenhouse set for a 16L 8D photoperiod. Aqueous extracts were made from marigolds, garlic, beans and potatoes using the same procedure as in field tested extracts. In all greenhouse experiments young undamaged leaves collected from potato plants in the border row from the field experiment were wetted to the point of run-off with the aqueous plant extracts. There were two other treatments, one consisting of wetting the leaves to the point of run-off with distilled water and the other of no treatment at all. The leaves were then reduced to the uppermost five leaflets. A single leaf was placed in each vial containing distilled water. In the first experiment approximately 100 adult PFB's collected from a potato field plot, were released within the cage. Forty-eight hours later the leaves were removed from the vials and the number of holes in each leaf were counted to assess damage. In the remaining experiments two field collected CPB larvae and 2 adults were placed at the base of each leaf in experiments 2 and 3 respectively. After 48 hours the percent damage was assessed. The estimated percentage of the leaf consumed was used as a measure of damage. Damage was assessed by close examination of each of the five leaflets on each

Fig. 2.

Randomized block design for greenhouse experiments. M = aqueous marigold extract spray, G = aqueous garlic extract spray, B = aqueous bean extract spray, P = aqueous potato extract spray, W = distilled water spray, N = untreated control.


M G B W P N
B N M P G W
P W G N M B
N B M P W G
W G N B M P
M P W G N B
15.24cm
15.24cm

leaf. An estimation of the percentage of each leaflet consumed was recorded with 20 the maximum percent consumed. The percent damage was then added for each of the 5 leaflets to give the total percent damaged for the leaf based on 100%.

Data from field and greenhouse experiments were examined using analysis of variance and Duncan's New Multiple Range Test.

RESULTS AND DISCUSSION

Field Experiment - Treatments

All data were compared to the Agway garden spray control treatment at the .01 and .05 level of significance (Tables 3 and 4). A significant difference in the insect counts indicates that there were fewer insects in the garden spray control compared to other treatments. A significant difference for damage assessment indicates that the amount of plant damage was less in the garden spray control than in other treatments. Although potato flea beetle (PFB) damage was also assessed it was minimal compared to the heavy damage sustained by the potato plants infested with a large number of Colorado potato beetles (CPB). PFB damage was taken into account, however, during damage assessment of the plant, but in no case did it ever amount to more than 5% of the total damage.

The companionate bean, garlic and marigold treatments were the last to show any significant difference in damage from the control (Table 3). This indicates that although damage did occur to the target plants in these treatments, it was delayed until the end of the growing season. In the companionate bean and marigold treatments none of the CPB larvae counts and only one of the CPB adult counts had any significance (Table 4). The reduced number of CPB larvae and adults, accounts for the delay in damage to these treatments. The companionate garlic however did have significant values for four of the CPB larvae counts (Table 4). It is interesting that, although CPB larvae were present on these target plants in significant numbers as early as 12 July they did not cause significant damage to the plant until 31 July (Table 3). Therefore, it cannot be assumed that because CPB larvae were on a potato plant that they were eating it, which seems to be the case with the companionate garlic treatment. However, close observations were not made on the comparative feeding behavior of CPB in any of the treatments. It may be that a chemical(s) from the garlic inhibited feeding by the CPB. Volatile chemicals released in the air from the "repellent" plants may affect the feeding behavior of the CPB on potato plants. The possibility of chemicals being released by the "repellent" plants into the soil and being absorbed by the potato plants thereby affecting the CPB's feeding is considered improbable because of the distance the chemical would have to travel and the ability of soil micro-organisms to degrade the chemical (Whittaker and Fenny, 1971). Further experimentation in this area is needed.

In all other treatments damage significantly greater than on the pesticide-sprayed target plants was sustained earlier in the growing season (Table 3). The companionate plastic fern and potatoes alone treatments had significant

Table 3. Significant difference between the control garden spray treatment and all other treatments for damage assessments and tuber weights

	Companionate Beans	Companionate Garlic	Companionate Marigolds	Companionate Potatoes	Companionate Plastic Ferns	Aqueous Bean Spray	Aqueous Garlic Spray	Aqueous Marigold Spray	Aqueous Potato Spray	Distilled Water Spray	Potatoes Alone No Treatment
Potato Flea Beetle Damage 2 July	**	*	*	**		*	*	*	**	*	**
Plant Damage 12 July				*		*	*	**	**	**	
Plant Damage 20 July				**	**	**	**	**	**	**	**
Plant Damage 31 July	**	**	**	**	**	**	**	**	**	**	**
Tuber Weights 20 August	**	**	**	**	**	**	**	**	**	**	**

* = $p < .05$
** = $p < .01$

Table 4. Significant difference between the control garden spray treatment and all other treatments for Colorado potato beetle larvae and adult counts - 1973

	TREATMENTS										
	Companionate Beans	Companionate Garlic	Companionate Marigolds	Companionate Potatoes	Companionate Plastic Ferns	Aqueous Bean Spray	Aqueous Garlic Spray	Aqueous Marigold Spray	Aqueous Potato Spray	Distilled Water Spray	Potatoes Alone No Treatment
LARVAE											
12 July		*			*			**	**	**	**
19 July		**					*				
26 July		**				*	**				
3 August		*			*	*				*	*
9 August						**			**	**	**
ADULTS											
26 July					**		**		**	**	
9 August	*		*	*							

* = $p < .05$
** = $p < .01$

damage to the target plants by 20 July. These treatments also had significantly early infestations of CPB larvae by 12 July. The companionate plastic fern also had significantly higher numbers of CPB adults on the target crop on 26 July (Table 4). The remaining treatments of companionate potatoes; aqueous bean, garlic, marigold and potato sprays; and the distilled water spray, had significant damage to the target plants as early as 12 July (Table 3). The target plants in these treatments were the first to be defoliated. Adult (and possibly larval) CPB in these treatments were forced to migrate to other treatments. Riley (1876) has reported that the CPB is capable of migrating from potato field to potato field in search of food, however he didn't identify the stages involved. Spray marigold, spray potato and spray distilled water had early significant infestation of CPB larvae (12 July). Spray garlic had significant infestation of CPB larvae by 19 July. The spray potato and spray distilled water treatments had significantly higher numbers of CPB adults on 26 July (Table 4). The two remaining treatments, companionate potatoes and spray beans, in this early damaged group did not have a significantly higher number of CPB larvae on the target plants early in the growing season. The companionate potato treatment although sustaining significant early damage did not have significant numbers of CPB larvae and only one significant CPB adult count taken late in the season on the 9th of August. Although the numbers of CPB larvae were not significant early in the growing season on the spray bean or companionate potato treatments their numbers were high enough to cause significant early damage. The last three CPB larvae counts on the spray bean treatment were significant indicating that their numbers were increasing throughout the early part of the growing season.

In some cases a significant difference was found in CPB numbers early in the growing season and later during the growing season no significant difference was found among treatments. This is because the CPB pupates in the soil and no pupal counts were taken.

Although there were significant differences in the number of insects and damage in the treatments, the final judgment of the merits of companionate plantings and sprayings lies with the yields of tubers in each of the different treatments. The Agway garden spray control was significantly different, having a higher yield, from all the treated potato plants as well as the potato plants which were planted alone without any treatment. The treatments which were significantly different from the Agway garden spray control were not different from each other (Tables 3 and 5).

FIELD EXPERIMENT - TREATMENTS

Table 5. Results of Duncan's New Multiple Range Test at the 1% level of significance for tuber weights taken 20 August 1973

	Companionate Beans	Distilled Water Spray	Companionate Plastic Ferns	Aqueous Potato Spray	Companionate Potatoes	Aqueous Bean Spray	Aqueous Marigold Spray	Aqueous Garlic Spray	Potatoes alone no treatment	Companionate Garlic	Companionate Marigolds	Garden Spray Insecticide
Rp		0.34	0.36	0.37	0.37	0.38	0.38	0.39	0.39	0.39	0.40	0.40
	0.26	0.31	0.35	0.36	0.39	0.43	0.47	0.48	0.48	0.55	0.64	1.48

Greenhouse Experiment - Treatments

Data were compared at the .01 and .05 level of significance. Although the data were not significant for CPB larvae and adults it was significant for the PFB (Table 6). In this experiment with only aqueous extracts as a repellent for the PFB it was shown that potato plant leaves treated with potato plant extract were significantly more damaged than potato plant leaves treated with aqueous bean, marigold or garlic extract. These findings indicate that the aqueous extracts of the beans, marigolds and garlic may contain a substance(s) that is a repellent to the PFB or which will inhibit its feeding. However in the field this repellancy or feeding inhibition was not observed in any of the aqueous spray treatments as effective against the PFB. In the field none of the aqueous spray treatments were significantly different from each other when tested against PFB damage (Table 3). The difference in findings may be due to the rapid volatilization of the "repellent" chemical in the field situation due to environmental conditions such as weathering. In the greenhouse with a relatively more stable environment the "repellent" chemical may have taken a longer time to volatilize and therefore would prove to be a deterrent.

GREENHOUSE EXPERIMENT - TREATMENTS

Table 6. Results of Duncan's New Multiple Range Test at the 5% level of significance for potato flea beetle damage assessment.

Rp	24.38	25.64	26.30	26.89	27.39
Aqueous Garlic Spray	Aqueous Bean Spray	Aqueous Marigold Spray	No Treatment to Potato Leaf	Distilled Water Spray	Aqueous Potato Spray
6.83	9.67	12.17	22.00	26.83	45.50

CONCLUSIONS

From the results of both field and greenhouse experiments the following conclusions are drawn:

1. We partially disproved the null hypothesis that beans, garlic, and marigolds when grown as companionate crops with potato plants, or their aqueous extracts sprayed upon potato plants, would not repel insects injurious to potato plants. In the field experiment companionate beans and marigolds had a repellent effect on the CPB, whereas companionate garlic had a feeding inhibition effect. The greenhouse experiments, although not significant for the CPB, were significant for PFB damage. The greenhouse data indicate that a repellent and/or feeding inhibitor in the aqueous extract of beans, garlic and marigolds was effective in reducing damage to potato leaves from the PFB. Therefore a restatement of the null hypothesis would be that beans, garlic and marigolds when grown as companionate crops with potato plants, or their aqueous extract sprayed upon potato plants, would not protect the potato plants from injurious insects. We were unable to disprove the restatement of the null hypothesis.
2. The tuber yields from the Agway garden spray plots were significantly different from all other treatments

indicating greater yield from the garden spray. None of the companionate plantings or aqueous sprays were significantly different from each other or the treatment where potatoes were grown alone (Table 5). Therefore the use of garlic, green beans or marigolds as repellents for CPB potato is an ineffective control.

3. Companionate plantings or aqueous sprays from "repellent" plants do not protect potato plants from the CPB and PFB for a long enough period of time to recommend their use as a replacement for synthetic insecticides.
4. Companionate beans, garlic and marigolds delayed damage to the target potato plants for a period of approximately 3 weeks under the conditions of the 1973 experiment (Table 3). This delay in damage however, was nullified by the end of the growing season as demonstrated by the significant differences in tuber weights (Table 5).
5. The companionate plantings of beans and marigolds exerted a repellent effect during the early part of the growing season. This repellent effect may have occurred because other choices were available to the CPB's. If in fact an entire field were planted to potatoes and marigolds or beans, with no alternative choice available, it is possible that no repellancy would have been observed.

6. Insect counts may not necessarily be directly proportional to the amount of damage sustained by a plant. The companionate garlic treatment had significant numbers of CPB larvae on the potato plant early in the season, but the potato plants did not sustain significant early damage. This may have been due to a feeding deterrent produced by the garlic which affected the feeding of the CPB on potato plants.
7. Aqueous sprays may have been unsuccessful in the field (1) because of dilution or (2) because the "repellent" chemicals were highly volatile.

LITERATURE CITED

Dempster, J. P. 1969. Some effects of weed control on the numbers of the small cabbage white (*Pieris rapae* L.) on brussels sprouts. J. Appl. Ecol. 6:339-45.

Merrill, R. 1972. Ecological design in the organic garden: companion planting and natural repellents. Org. Gard. Farm. 19:48-53.

Philbrick, H. and R. B. Gregg. 1973. Companion Plants and How to Use Them. The Devin-Adair Co. Old Greenwich, Conn. 113 p.

Pimentel, D. 1961. Species diversity and insect population outbreaks. Ann. Entomol. Soc. Am. 54:76-86.

Pollard, E. 1971. Hedges VI. Habitat diversity and crop pests: a study of *Brevicoryne brassicae* and its syrphid predators. J. Appl. Ecol. 8:751-80.

Riley, C. V. 1876. Potato Pests. Orange Judd Co. New York, N. Y. 108 p.

Rodale, J. I. (ed.). 1969. The Organic Way to Plant Protection. Rodale Press, Inc. Emmaus, Pa. 355 p.

Rodale, R. (ed.). 1971. The Basic Book of Organic Gardening. Ballantine Books Inc. New York, N. Y. 377 p.

Root, R. B. 1973. Organization of a plant-arthropod association in simple and diverse habitats: the fauna of collards (*Brassica oleracea*). Ecol. Monogr. 43:95-124.

Smith, J. G. 1969. Some effects of crop background on populations of aphids and their natural enemies on brussels sprouts. Ann. Appl. Biol. 63:326-30.

Tahvanainen, J. O. and R. B. Root. 1972. The influence of vegetational diversity on the population ecology of a specialized herbivore, *Phyllotreta cruciferae* (Coleoptera: Chrysomelidae) Oecologia (Berl). 10:321-46.

Whittaker, R. H. and P. P. Feeny. 1971. Allelochemics: Chemical interactions between species. Science. 171:757-70.

APPENDIX

KEY TO APPENDIX

PFB = Potato flea beetle

CPB = Colorado potato beetle

B = blocks

P = plants

T = treatments

* = significance at the 5% level

** = significance at the 1% level

CB = companionate beans

CG = companionate garlic

CM = companionate marigolds

CP = companionate potatoes

CPL = companionate plastic ferns

SB = aqueous bean spray

SG = aqueous garlic spray

SM = aqueous marigold spray

SP = aqueous potato spray

SW = distilled water spray

SGS = multi-purpose fruit spray

P = potatoes without any spray or companionate plants

LITERATURE REVIEW

Insects Harmful to Potatoes

There are over 20 major insect pests of potatoes throughout the United States (Shands and Landis, 1970). In many areas only a small number of these insects become a problem. In the northeastern United States, particularly in Massachusetts and Connecticut, recommendations for control of potato pests are given for eight insects. These insects include the potato flea beetle, *Epitrix cucumeris* (Harris); Colorado potato beetle, *Leptinotarsa decemlineata* (Say); European corn borer, *Pyrausta nubilalis* (Hubner); cabbage looper, *Trichoplusia ni* (Hubner) and a variety of species of leafhoppers, aphids, cutworms and wireworms (Hawkins, et al., 1973).

Control of Potato Insects

Chemical Control

First attempts to control potato insects, particularly the Colorado potato beetle, utilized a mixture of paris green and flour in the proportion of 1 - 50 respectively. This mixture proved very effective. Two other recommended compounds were "Potato Pest Poison" composed of one part pure salt and one part arsenate of soda and "pest poison" composed of arsenate of sodium and common table salt (Riley, 1876). Later recommendations included the use of london purple (Sempers, 1894). Bordeaux mixture was found to be an excellent repellent of the potato flea beetle and arsenate of lead was recommended for control of the Colorado potato beetle. Insect infected potatoes could be treated by fumigation with carbon bisulfide (Sanderson, 1912). A tobacco extract was recommended for controlling aphids and leafhoppers on potatoes (Sanderson and Peairs,1921). Dusting with sodium fluosilicate gave good control of certain species of blister beetles and nicotine sulfate was used to control the potato aphid (Metcalf and Flint, 1928). Along with paris green and the arsenates, cryolite was added as a control for the Colorado potato beetle. Barium fluosilicate or cryolite was added to the list of chemical controls for blister beetles with sulfur and pyrithrum being added to the recommendations to control leafhoppers (Metcalf and Flint, 1939). After its discovery in the 1940's, DDT was recommended as a control for all potato insects (Metcalf, et al., 1951). Soon after its discovery came numerous other synthetic organic insecticides some of which are recommended for use on todays potato crops. Fifteen insecticides are currently recommended for control of various potato insects in Massachusetts and Connecticut. These include carbaryl (Sevin*), Guthion*, methoxychlor, Diazinon*, parathion, Monitor*, endosulfan (Thiodan*), Meta-Systox-R*, Lannate*, Phosdrin*, TEPP, nicotine

*Trade name

sulfate, dimethoate (Cygon*), chlordane and DiSyston* (Hawkins, et al., 1973).

Non-Chemical Control

Initial recommendations to control potato pests were that the grower encourage natural enemies and handpick or use a mechanical device to destroy them. Another method utilized a mixture of chicken manure and ashes spread around the base of young plants. This mixture was to prevent the raising and cracking of the soil and thus prevent the Colorado potato beetle from hiding around the young plants at night or during cold weather. Additionally this mixture would invigorate the plants. The use of early varieties and crop rotations were also suggested. Above all, the potato field was to have been isolated as much as possible, either by using land surrounded by timber, or by planting in the center of a cornfield (Riley, 1876). Further recommendations included the use of nets to capture insects, shaking them off the plant into a bucket of kerosene oil and early or late plowings (Sempers, 1894). Burning of the vines or releasing of sheep and hogs into the field to eat the vines as soon as the tubers had been dug, removal of diseased plants, removal of alternate hosts, flooding fields after harvest and clean farming were advocated (Sanderson, 1912). It was recommended that farmers should encourage the presence of insectivorous

*Trade name

birds and predaceous insects and that these creatures should be protected as far as possible (Lochhead, 1919). Rose-bushes should not be permitted to grow in abundance near potato fields as they afford a place for the overwintering eggs of aphids (Metcalf and Flint, 1928). Many of these cultural approaches were utilized up to the 1940's. Then with the discovery of DDT all non-chemical control measures were laid aside. DDT could be used effectively as a control for all potato pests.

Organic Gardening

It wasn't until the early 1960's that the public became more aware and concerned about contamination of the environment. This was brought about by the book "Silent Spring" written by Rachel Carson. Because of pesticide contamination of the environment, concerned people began looking for alternative methods in which to protect their gardens. Many of them turned to organic gardening. Organic gardening is the maintenance of soil fertility and texture by replenishing soil with readily decomposable and easily reassimilated materials. Natural animal manures, crop residues and compost are used. The organic method also bans the use of artifical chemical fertilizers and toxic pesticides while advocating the use of naturally occurring minerals (Rodale, 1971).

The variety of different pest control methods currently used by organic gardeners had been advocated as commercial agricultural pest control methods before the use of chemicals. These methods are advocated by organic gardeners because they harmonize with the existing ecosystem. One method recommended is the use of companionate planting techniques. Beans, garlic and marigolds have been reported in the popular literature to have a repellent effect on some insects (Rodale, 1971; Hunter, 1971; Philbrick and Gregg, 1973). Grinding of "repellent" plants and diluting with water to form a spray has also been recommended (Rodale, 1971). These popular reports, however, lack any sound experimental basis. Some experimental research has been conducted with plants and their extracts to determine if they possess any repellent or insecticidal properties.

Experiments with garlic have demonstrated that both the crude extract and the oil fraction extracted from garlic (*Allium sativum*) are larvicidal in nature and active against 3rd stage larva of *Culex peus* Speiser, *C. tarsalis* Coquillett, *Aedes aegypti* (L.), *A. triseriatus* (Say), *A. sierrensis* (Ludlow), and 3rd and 4th stage larvae of highly insecticide resistant strains of *A. nigromaculis* (Ludlow) (Amonkar and Reeves, 1970). Later the larvicidal principles were isolated and identified as diallyl disulfide and diallyl trisulfide. Both natural and synthetic samples of these larvicides are fatal at 5 ppm to *Culex pipiens quinquefasciatus* (Say), (Amonkar and Banerji, 1971). Extracts have been made from 390 species of plants that were immune to attack of the Japanese beetle. Some extracts when tested against the Japanese beetle gave indications of repellency, however it was much less than that shown by powdered derris and pyrethrum (Metzger and Grant, 1932). Dethier (1941) demonstrated that essential plant oils at a certain level were normally an attractant to *Papilio ajax*, but in greater concentration acted as a repellent.

Intercropping Considerations

Although a great deal of scientific research has been conducted on the control of potato insects very little has been done on the potential of companionate planting (intercropping) as a means of protecting potato plants from phytophagous insects. Little work has been done with the effects of intercropping on vegetable crops in general. The reason for the lack of research in this area is because companionate planting on a large scale would be impractical because it would interfere with the planting, fertilizing, cultivating, harvesting, etc. of the major crop you would be trying to protect. Companionate planting is a method more suited to the home gardener.

One study has shown that when potatoes were intercropped with corn the first appearance of insects was observed approximately at the same time in both fields (intercropped and potatoes not intercropped). As the crops grew it became evident that insects were more abundant in monocrop fields than in intercropped fields. This was mainly due to the slower rate of aphid reproduction in intercropped fields. Similarly it was observed that natural enemies of the aphids were also lower in intercropped than in monocropped fields. Data on yields were not available (Hukusima, 1959).

Lower (1972) found no difference in the numbers of cucumber beetles, *Acalymma vittatum* (Fabricius) and *Diabrotica undecimpunctata* (Barber), on the test cultivar (*Cucurbita pepo* L.) when surrounded by *Cucurbita pepo* than on *C. pepo* surrounded by different varieties of cucumbers. However, a higher percentage of the test cultivars of other species were damaged when *Cucurbita pepo* was the surrounding cultivar. This finding indicates that planting *Cucurbita pepo* as a trap crop for pickleworm, *Diaphania nitidalis* (Stoll), may lead to greater beetle damage and the gain in control of one insect may be offset by loss in control of the other.

Intercropping with grains and forage crops has been practiced for more than 50 years. Companion or nurse crops can provide a return from the land during the seedling year, control the growth of annual weeds and help prevent water and wind erosion. Most experiments involving intercropping have been attempts to increase yield. Studies have shown that time of harvest of the nurse crop, type of companionate crop and environmental conditions are very critical to the yield of alfalfa. In 1908 nurse crops such as rye, wheat, oats and barley were observed to hinder the development of the tops and roots of alfalfa. Thick stands were especially detrimental to alfalfa. After removal of the nurse crop the weak and underdeveloped alfalfa plants were poorly fitted to withstand drought (Clark, 1908). Sudan grass, millet and soybeans when planted with alfalfa and cut at a height of three inches, resulted in fairly good alfalfa yields in the first cutting. Yields and establishment of alfalfa were unsatisfactory when sudan grass, buckwheat, millet and soybeans were used as a companion crop and cut for grain (Briggs and Harrison, 1953). With the use of oats as a companion crop less soil moisture and light was available to the alfalfa seedlings but weeds were less numerous both before and after removal of the mature oat crop than when oats were harvested earlier. Slightly thinner alfalfa strands resulted from oats harvested at maturity, but alfalfa forage yields were comparable to other treatments (Klebesadel and Smith, 1960). Peters (1961) demonstrated that legume yields were lowest when seeded with oats and that oats frequently will be much more competitive than weed growth which will flourish in their absence. During the seedling year when alfalfa was established with the use of herbicides the yields were comparatively unproductive and much higher forage yields were obtained when alfalfa was established with an oat companionate crop and both harvested as forage (Kust, 1968). Further research has shown that higher yields of alfalfa were obtained at the lower seeding rate of 3 and 10 kg/ha using EPTC and benefin than at seeding rates of 17 and 24 kg/ha using 2,4-DB plus dalapon, oats or check (Moline and Robison, 1971). The net return (excluding costs common to all methods) favored alfalfa establishment with oats harvested for grain and straw. However, stand counts of alfalfa in the fall of the seeding year were generally higher for alfalfa grown without a companionate crop (Schmid and Behrens, 1972). The performance of berseem clover (*Trifolium alexardrinum*) as a companion crop of alfalfa or alfalfa-timothy mixture gave erratic results. High temperature seemed to reduce the growth of clover allowing an increased growth of annual weeds (Nelson, et al., 1965).

Alfalfa has been used as a companion crop with crown-vetch. The presence of alfalfa in the seeding mixture depressed crown vetch establishment and long term yields.

Mixtures of crownvetch with fescue or orchardgrass produced more total forage than crownvetch planted alone in two out of four years, but there were severe crownvetch stand losses by the fourth year (Mays and Evans, 1972).

Oats have also been used as a companion crop for red clover. Pendleton and Dungan (1953) demonstrated that in no oat seeding arrangement did the red clover population, early growth or hay yield equal those of plots where red clover was seeded alone. The difference in the amount of companion crops sown per unit area can affect the size of legume plants (red clover and alfalfa). A greater weed population was present in plots sown with oats (companion crop) at a low rate. As a result the numbers of alfalfa and red clover plants were not significantly different in tests of various varieties and sowing rates of oats. However, individual legume plants were somewhat larger under the lower oat sowing rates (Bula, et al., 1954). Oats have been shown to be detrimental to the production of bromegrass and red clover. Plants of bromegrass (exclusive of roots) seeded without a companion crop ranged from 4-17 times heavier and produced from 2-5 times more tillers than similar plants seeded without oats (Lueck, et al., 1949). Whether due to shading effects, competition for moisture, nutrient requirements or other factors, oat varieties may cause measureable difference in the stand and development of red clover plants during the first growing season (Collister and Kramer, 1952). Smith, et al.,(1954) demonstrated that four different varieties of oats, Clinton, Bonda, Vicland and Forvic showed no significant differences on the establishment of legume stands (alfalfa and red clover).

Because of competition for light, moisture and soil nutrients the best nurse crops are short, erect growing non-lodging varieties which mature early and have few leaves (Hughes and Wilkins, 1935). Laboratory studies have demonstrated that reduced light intensity caused a reduction in the dry weight of plants, a reduction in the growth response to nitrogen fertilizer and a decrease in nodulation in alfalfa. Oats used as a companion crop in the field may shade plants and cause the same effects (Pritchett and Nelson,1951). Andrews (1974) demonstrated that 27% more total grain yield (sorghum and early cereal) was obtained when dwarf varieties of sorghum were intercropped with early cereals instead of intercropping with tall varieties of sorghum.

Cereal companion crops can increase the forage produced in the first year of sowing while still allowing good growth and seed production of subterranian clover (McGowan and Williams, 1971). Wheat used as a companion crop did not affect the establishment of Russian wild rye grass but it did decrease the vigor of the grass plants as was reflected in lower seed yields. The higher the plant density of the companion crop the greater the depression on seedling vigor and production of the grass crop, and the higher the yield of wheat (Lawrence, 1967, 1970). Winter cereals (rye and wheat) caused reduced legume (red clover and alfalfa) stands and hay yields. This reduction in yield was due to the strong competition from winter rye and wheat for light and soil moisture. The winter companion crops extend their competitive effects over a much longer period of time than do the spring sown companion crops (Klebesadel and Smith, 1959).

Maize is still another crop which has been utilized as a companion crop. Maize intercropped with either beans or cow peas decreased the total yield of grain per hactare. However, intercropping sorghum with pigeon peas did increase the total grain per hectare (Enyi, 1973). Groundnut interplanted with cotton did not affect the yield of cotton and an early crop of groundnut was produced (Varma and Subba Rao Kanke, 1969).

Although it was common practice to make spring seedings of legumes with small grain companion crops to increase legume seeding establishment it was demonstrated that seeding without a companion crop was a means of increasing chances of successful establishment of birdsfoot trefoil. Companion crops significantly reduced stands and yields of birdsfoot trefoil under all management studies (Scholl and Staniforth, 1957). Root growth and competition is also affected by companion crops. Vertical and lateral root growth of alfalfa, birdsfoot trefoil and orchardgrass was reduced when they were established with a companion crop of barley. Mature barley was also found to intercept 89% of the incident light in early morning and 22% at noon. Soil moisture content and soil temperatures were found to be lower under the barley companion crop (Cooper and Ferguson, 1964). P^{32} tagged solid fertilizer and phosphoric acid were used to evaluate root competition for phosphorous between several groups of interplanted row crops in the greenhouse. In the corn-bean, corn-sesame, corn-castor bean plantings corn was the most effective feeder of fertilizer phosphorous (Lai and Lawton, 1962).

Companionate crops can provide a return from the land as well as control the growth of annual weeds and help prevent water and wind erosion. However, these advantages must be weighted against the ability of the companion crop to compete with the major crop. Important considerations must be given to the choice, time of planting, sowing rate and time of harvest or cutting of the companion crop if the final product is to be of greater yield than if the major crop were planted alone.

Ecological Considerations

According to the "Resource Concentration Hypothesis" herbivores are more likely to find and remain on hosts that are growing in dense or nearly pure stands and the most specialized species frequently attain higher relative densities in such simple environments. As a result, biomass tends to become concentrated in a few species, causing a decrease in the species diversity of herbivores in pure stands (Root, 1973). Monocultures are also colonized more rapidly and exhibit greater feeding damage than diverse stands as, for example, when collards are interplanted with tomatoes and tobacco (Tahvanainen and Root, 1972). These results demonstrated that vegetational diversity can exert a direct influence on populations of phytophagous insects. Species diversity, both faunal and floral, within a habitat is an important factor in stabilizing the habitat and suppressing population outbreaks in communities. This principle has application in agricultural crop protection (Pimentel, 1961). Weeds add to the diversification of the agroecosystem. Dempster (1969) showed that *Pieris rapae* numbers were low in weedy plots but that the advantageous effects of the weeds were outweighed by the harmful effects of competition between the weed and the crop. Yield was highest on those plots which were kept free of weeds. Alate aphids *Brevicoryne brassicae* and white flies, *Aleyrodes brassicae* were shown to colonize sprout plants in bare soil more than sprout plants in weedy plots and that larger populations developed on the bare-soil plants (Smith, 1969). Diversity of the habitat outside the crop may not add to the stability of crop pest populations. Diversity of habitats outside the crop area made no difference to syrphid predation on Brevicoryne brassicae as compared with a largely arable area (Pollard, 1971). In other studies, diversity outside the crop area did reduce the number of cabbage aphids at the edge of the crops more than at the center. This was due to the presence of more predators and parasites at the edge of the crop. The increase in predators and parasites was probably due to the presence of the edgegrowth and particularly of the flowers which encouraged syrphids to lay eggs nearby. Physical factors at the sheltered edge (uncultivated land) acted through effects on the host plants to reduce the reproduction rate of the aphids (van Emden, 1965). Uncultivated land (especially if not regularly cut), therefore appears to support a high percentage of carnivorious insects and may serve as a general reservoir of parasites and predators (van Emden, 1962). Field observations showed that potato flea beetles were less prevalent on plants where larger trees cast dense shade. There was, however, a decrease in the rate of injury with increase in distance from the uncultivated areas. This was probably due to the fact that a significantly higher number of flea beetles were found to be hibernating in the uncultivated field than in the potato field. No data was given on yields (Wolfenbarger, 1940). Hedgerows may also serve as a reservoir for insects other than those damaging the crops. Hedgerows have an especially rich flora of woodland shrubs and trees with various grasses and herbs and they usually support more species of insects than the neighboring crops. Of the terrestrial communities, that on the hedge was the most diverse, less so in the bean field and least in the pasture. The diversity of the aerial population decreased with increased distance from the hedge. The presence of the hedge enriched the aerial population nearby for a distance of three to ten times its height to the leeward side and one-two times to the windward side (Lewis, 1969a). This diversity of insects in and around the hedge row may be due to the fact that fewer insects accumulate in slow winds than in fast, which suggests that accumulation near hedges occurs largely because the patterns of air flow created by the hedge concentrated insects from the passing aerial population, not because the hedge itself supplies the greater insect population. The slow laminar flow of air over hedgerows allows insects to be carried away from the hedgerow. The more turbulent air flow on the leeward side of the hedgerow caused by high wind velocity causes insects to be deposited in this area thus increasing the insect population of the hedgerow (Lewis, 1965, 1966, 1969b).

ADDITIONAL RESULTS AND DISCUSSION

Field Experiment - Blocks

A Duncan's New Multiple Range Test was conducted on blocks so that we might speculate on the effects of surrounding diverse vegetation on the population of pestiferous insects affecting potatoes as well as yields of potatoes.

Blocks were numbered relative to the amount of surrounding vegetational diversity with one indicating high vegetational diversity and six indicating low vegetational diversity. All data was compared to block one at the 5% level of significance. Block one was chosen to compare to all other data because it was assumed that there would be less damage in this area of the field as a result of the high amount of surrounding vegetational diversity which might harbor predators/parasites of the CPB which would limit their numbers (Nat. Acad. Sci. 1969). No counts were made of predators, parasites, predation or parasitism. Counts were made of only the larvae and adults of the CPB.

Significant differences were first observed (12 July) in the number of CPB larvae in blocks five and six. Both of these blocks were in an area of the field of low vegetational diversity and possibly less predator/parasite activity. By 9 August all blocks had significantly higher numbers of of CPB larvae than block 1. Adult CPB numbers never reached significant proportions in block six (least diverse area). This could be due to the lack of predators/parasites in this area which allowed for a rapid increase in the number of CPB larvae in the beginning of the season (12 July). This rapid increase in CPB larvae population would lead to rapid destruction of the target plants. The CPB adults would then be forced to migrate to adjacent blocks. Because of previous significant damage to target plants in block six on 20 July and 3 August they were unable to support a large number of CPB adults. Emigration from block six could then account for the significant numbers of CPB adults in block five on both the 3rd and 9th of August. Block 2 also experienced a significant number of CPB adults on the 3rd and 9th of August which may also have been due to emigration from surrounding blocks. Block 2 was a relatively green area as compared to blocks 3, 4, 5 and 6 and offered food and shelter to migrating CPB's. Block three and four were intermediate in their surrounding vegetational diversity and only demonstrated significant differences once in the number of CPB adult counts throughout the growing season. Block three may have experienced immigration from block six with which it was adjacent. Although most of the significance is explained by migration, pupation may have played a large part. We have considered (possibly erroneously) that developmental rates of the CPB did not vary from block to block and could therefore be neglected as a source of variance in the number of CPB adult and larvae counts.

Although sample aphid counts were taken they will not be considered. Plant damage caused sampling problems which made random sampling of aphids almost impossible.

As would be expected damage was first significant in the area of least vegetational diversity (block six). The second and third damage assessments show significantly less damage in the two areas of high vegetational diversity (block one and two). Finally, the tuber weights of block one were significantly higher than tuber weight in any of the other blocks indicating less plant damage and possibly more predator/parasite activity.

Speculative conclusion: 1. Predators and/or parasites may keep down CPB numbers in areas of high vegetational diversity. 2. The possibility may exist for the use of vegetational diversity in an integrated pest management program but at the present time further research will be needed along these lines.

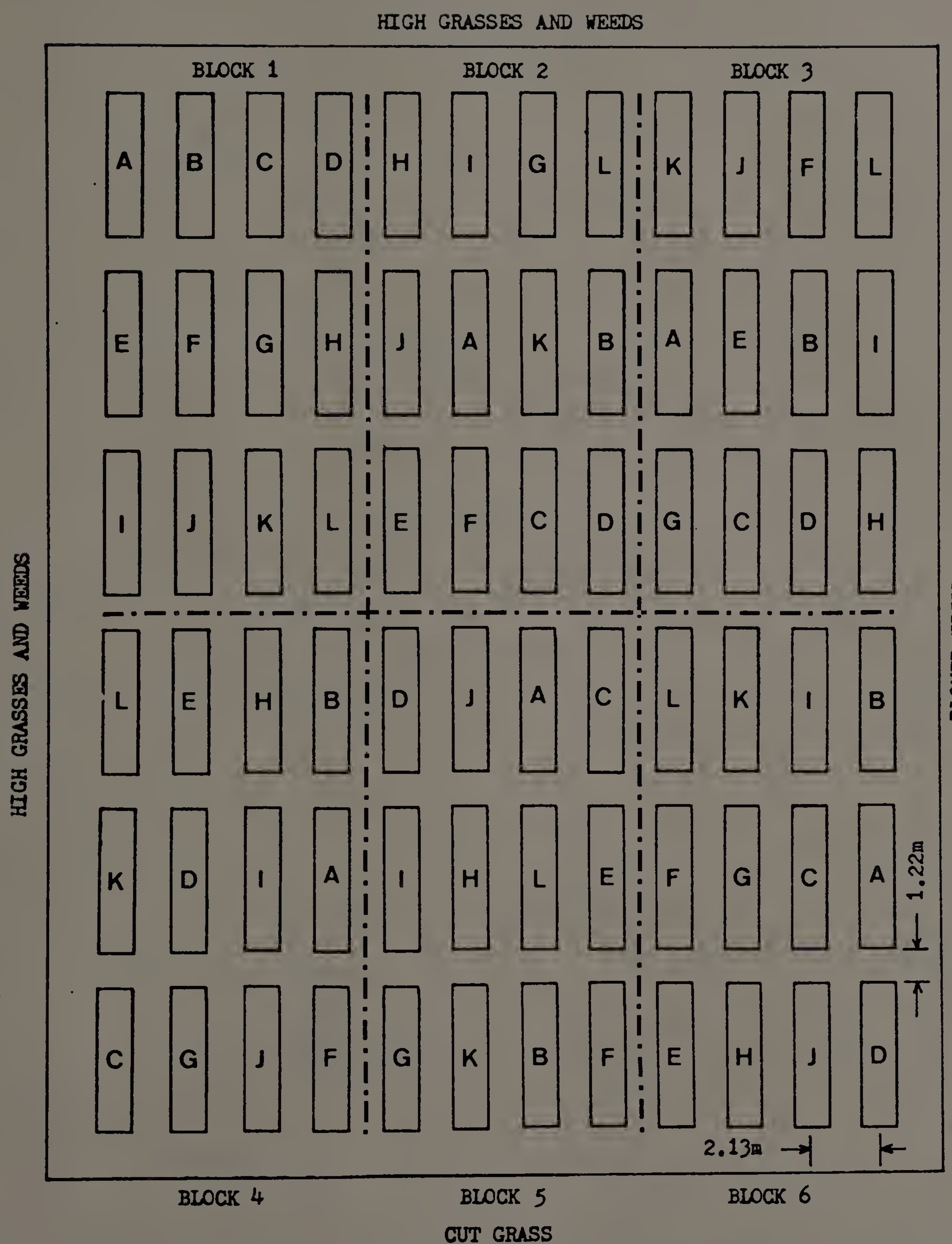
Greenhouse Experiment - Blocks

Although there was a significant difference among the blocks in the greenhouse experiment no one factor seems to be obviously responsible. At the present time it is unknown what factor(s) caused this difference among the blocks.

Table 7. Significant difference between block 1 and all other treatments. * indicates significant difference at the 5% level and ** indicates significant difference at the 1% level.

	2	3	4	5	6
CPB LARVAE 12 July 1973				*	*
CPB LARVAE 3 August 1973	*				
CPB LARVAE 9 August 1973	**	**	**	**	**
CPB ADULTS 3 August 1973	*	**		*	
CPB ADULTS 9 August 1973	*		*	*	
POTATO FLEA BEETLE DAMAGE			**		
APHIDS 19 July 1973	*				*
PLANT DAMAGE 12 July 1973					**
PLANT DAMAGE 20 July 1973		**	*	**	**
PLANT DAMAGE 31 July 1973		**	**	**	**
TUBER WEIGHTS 20 August 1973	**	**	**	**	**

Fig. 3. Randomized block design for field experiment. A = companionate beans, B = distilled water spray, C = aqueous marigold extract spray, D = companionate plastic ferns, E = companionate marigolds, F = untreated control, G = aqueous garlic extract spray, H = aqueous bean extract spray, I = aqueous potato extract spray, J = multi-purpose fruit spray, K = companionate potatoes, L = companionate garlic.


HIGH GRASSES AND WEEDS
BLOCK 1
BLOCK 2
BLOCK 3
A B C D H I G L K J F L
E F G H J A K B A E B I
I J K L E F C D G C D H
L E H B D J A C L K I B
K D I A I H L E F G C A
C G J F G K B F E H J D
1.22m
2.13m
HIGH GRASSES AND WEEDS
PLOWED FIELD
BOARDER ROW OF POTATOES
BLOCK 4
BLOCK 5
BLOCK 6
CUT GRASS

FIELD EXPERIMENT

Table 8. Analysis of variance for CPB larvae count taken 3 July 1973

ANOVA

Source	df	SS	MS	Observed F
Total	287	48444.88		
B	5	721.04	144.21	1.13
T	11	5571.88	506.53	1.90
BT (Error)	55	14679.46	266.90	
P(BT)(Error)	216	27472.50	127.19	

Table 9. Analysis of variance for CPB larvae count taken 12 July 1973.

ANOVA

Source	df	SS	MS	Observed F
Total	287	20276.66		
B	5	600.49	120.10	2.25*
T	11	4360.74	396.43	5.77**
BT (Error)	55	3781.43	68.75	
P(BT) (Error)	216	11534.00	53.40	

FIELD EXPERIMENT

Table 10. Analysis of variance for CPB larvae count taken 19 July 1973.

ANOVA

Source	df	SS	MS	Observed F
Total	287	167418.88		
B	5	2741.92	548.38	1.38
T	11	29017.29	2637.94	2.92**
BT (Error)	55	49747.67	904.50	
P(BT)(Error)	216	85912.00	397.74	

Table 11. Analysis of variance for CPB larvae count taken 26 July 1973.

ANOVA

Source	df	SS	MS	Observed F
Total	287	229099.11		
B	5	4058.11	811.62	1.32
T	11	38445.19	3495.02	3.59**
BT (Error)	55	53516.31	973.02	
P(BT) (Error)	216	133079.50	616.11	

FIELD EXPERIMENT

Table 12. Analysis of variance for CPB larvae count taken 3 August 1973.

ANOVA

Source	df	SS	MS	Observed F
Total	287	134941.88		
B	5	4882.21	976.44	2.95*
T	11	20427.46	1857.04	2.69**
BT(Error)	55	38015.71	691.20	
P(BT)(Error)	216	71616.50	331.56	

Table 13. Analysis of variance for CPB larvae count taken 9 August 1973.

ANOVA

Source	df	SS	MS	Observed F
Total	287	160245.88		
B	5	19005.29	3801.06	11.18**
T	11	29654.88	2695.90	3.89**
BT(Error)	55	38114.21	692.99	
P(BT)(Error)	216	73471.50	340.15	

FIELD EXPERIMENT

Table 14. Analysis of variance for CPB adult count taken 3 July 1973.

ANOVA

Source	df	SS	MS	Observed F
Total	287	67.33		
B	5	1.23	0.25	1.04
T	11	2.62	0.24	1.20
BT(Error)	55	11.23	0.20	
P(BT)(Error)	216	52.25	0.24	

Table 15. Analysis of variance for CPB adult count taken 12 July 1973.

ANOVA

Source	df	SS	MS	Observed F
Total	287	22.89		
B	5	0.63	0.13	1.54
T	11	0.88	0.08	1.14
BT(Error)	55	3.88	0.07	
P(BT)(Error)	216	17.50		

FIELD EXPERIMENT

Table 16. Analysis of variance for CPB adult count taken 19 July 1973.

ANOVA

Source	df	SS	MS	Observed F
Total	287	147.97		
B	5	4.20	0.84	1.83
T	11	8.93	0.81	1.25
BT (Error)	55	35.59	0.65	
P(BT) (Error)	216	99.25	0.46	

Table 17. Analysis of variance for CPB adult count taken 26 July 1973.

ANOVA

Source	df	SS	MS	Observed F
Total	287	4010.65		
B	5	75.65	15.13	1.38
T	11	672.90	61.17	3.74**
BT (Error)	55	899.10	16.35	
P(BT) (Error)	216	2363.00	10.94	

FIELD EXPERIMENT

Table 18. Analysis of variance for CPB adult count taken 3 August 1973.

ANOVA

Source	df	SS	MS	Observed F
Total	287	26997.50		
B	5	1127.89	225.58	3.20**
T	11	2797.46	254.91	1.79
BT (Error)	55	7824.90	142.27	
P(BT)(Error)	216	15247.25	70.60	

Table 19. Analysis of variance for CPB adult count taken 9 August 1973.

ANOVA

Source	df	SS	MS	Observed F
Total	287	39207.22		
B	5	926.99	185.40	2.41*
T	11	9379.68	852.70	3.82**
BT(Error)	55	12286.30	223.39	
P(BT)(Error)	216	16614.25	76.92	

FIELD EXPERIMENT

Table 20. Analysis of variance for flea beetle damage assessment taken 2 July 1973.

ANOVA

Source	df	SS	MS	Observed F
Total	71	1480.99		
B	5	433.90	86.78	7.17**
T	11	381.49	34.68	2.87**
BT (Error)	55	665.60	12.10	

FIELD EXPERIMENT

Table 21. Analysis of variance for assessment of plant damage taken 12 July 1973.

ANOVA

Source	df	SS	MS	Observed F
Total	287	219281.16		
B	5	9697.31	1939.46	3.58**
T	11	35494.71	3226.79	3.11**
BT (Error)	55	57095.40	1038.10	
P(BT)(Error)	216	116993.74	541.63	

Table 22. Analysis of variance for assessment of plant damage taken 20 July 1973.

ANOVA

Source	df	SS	MS	Observed F
Total	287	232511.11		
B	5	22794.44	4558.89	9.31**
T	11	48906.94	4446.09	4.45**
BT (Error)	55	54984.72	999.72	
P(BT)(Error)	216	105825.01	489.93	

FIELD EXPERIMENT

Table 23. Analysis of variance for assessment of plant damage taken 31 July 1973.

ANOVA

Source	df	SS	MS	Observed F
Total	287	273496.88		
B	5	51196.88	10239.38	21.20**
T	11	48509.38	4409.94	3.49**
BT(Error)	55	69478.12	1263.24	
P(BT)(Error)	216	104312.50	482.93	

Table 24. Analysis of variance for tuber weights taken 20 August 1973.

ANOVA

Source	df	SS	MS	Observed F
Total	287	77.65		
B	5	16.43	3.29	32.90**
T	11	26.99	2.45	11.67**
BT(Error)	55	11.57	0.21	
P(BT)(Error)	216	22.66	0.10	

FIELD EXPERIMENT

Table 25. Statistics of larval counts taken 12 July 1973

VARIABLE	MEAN	S.D.	RANGE
CB	0.54	1.18	4.00
SW	12.75	7.93	36.00
SM	9.21	10.41	46.00
CPL	6.83	8.52	37.00
CM	4.63	6.36	21.00
P	12.38	13.46	45.00
SG	4.29	4.36	15.00
SB	5.33	5.95	20.00
SP	9.58	8.11	31.00
SGS	0.00	0.00	0.00
CP	4.58	6.49	23.00
CG	5.96	7.93	26.00

FIELD EXPERIMENT

Table 26. Statistics of larval counts taken 19 July 1973.

VARIABLE	MEAN	S.D.	RANGE
CB	3.00	8.16	34.00
SW	15.75	20.23	70.00
SM	19.63	27.01	99.00
CPL	14.58	13.99	44.00
CM	9.17	14.45	61.00
P	17.67	18.67	58.00
SG	25.42	29.56	117.00
SB	15.92	27.47	122.00
SP	19.83	30.94	113.00
SGS	0.00	0.00	0.00
CP	10.17	10.89	36.00
CG	40.13	36.81	114.00

Table 27. Statistics of larval counts taken 26 July 1973.

VARIABLE	MEAN	S.D.	RANGE
CB	1.21	2.75	10.00
SW	16.42	19.37	75.00
SM	18.50	31.91	138.00
CPL	19.83	21.71	61.00
CM	15.71	21.95	68.00
P	19.63	27.24	92.00
SG	31.25	36.89	149.00
SB	25.79	45.27	151.00
SP	16.71	28.30	86.00
SGS	0.71	2.18	9.00
CP	9.50	13.75	60.00
CG	44.42	28.07	102.00

FIELD EXPERIMENT - TREATMENTS

Table 28. Statistics of larval counts taken 3 August 1973.

VARIABLE	MEAN	S.D.	RANGE
CB	0.29	1.23	6.00
SW	21.25	28.68	111.00
SM	13.71	13.49	42.00
CPL	21.67	18.29	59.00
CM	5.00	8.22	33.00
P	21.63	26.73	100.00
SG	18.13	25.35	115.00
SB	24.38	30.11	119.00
SP	19.17	25.17	96.00
SGS	3.75	8.60	34.00
CP	3.63	6.29	26.00
CG	21.17	23.67	79.00

Table 29. Statistics of larval counts taken 9 August 1973.

VARIABLE	MEAN	S.D.	RANGE
CB	0.13	0.45	2.00
SW	25.08	29.06	103.00
SM	20.00	17.72	67.00
CPL	14.42	15.46	68.00
CM	2.50	4.60	15.00
P	25.08	23.33	69.00
SG	18.79	29.90	136.00
SB	29.75	32.61	121.00
SP	25.38	38.58	162.00
SGS	4.83	6.19	26.00
CP	1.38	2.04	7.00
CG	16.42	15.07	53.00

FIELD EXPERIMENT - TREATMENTS

Table 30. Statistics of plant damage assessment taken 12 July 1973.

VARIABLE	MEAN	S.D.	RANGE
CB	8.13	18.52	80.00
SW	32.92	26.70	90.00
SM	33.13	33.49	100.00
CPL	22.71	26.29	80.00
CM	10.42	11.88	35.00
P	22.08	22.50	85.00
SG	24.17	28.92	100.00
SB	30.42	36.62	100.00
SP	31.25	31.49	100.00
SGS	2.08	10.21	50.00
CP	29.38	33.79	100.00
CG	4.38	7.71	25.00

Table 31. Statistics of plant damage assessment taken 20 July 1973.

VARIABLE	MEAN	S.D.	RANGE
CB	14.17	17.80	65.00
SW	41.46	31.02	90.00
SM	36.25	30.26	100.00
CPL	30.00	30.61	100.00
CM	14.79	12.98	45.00
P	36.04	32.70	100.00
SG	33.54	26.06	85.00
SB	34.38	31.57	95.00
SP	44.79	32.22	100.00
SGS	1.46	6.16	30.00
CP	36.67	26.16	90.00
CG	13.13	13.34	45.00

FIELD EXPERIMENT - TREATMENTS

Table 32. Statistics of plant damage assessment taken 31 July 1973.

VARIABLE	MEAN	S.D.	RANGE
CB	43.75	23.04	75.00
SW	47.29	33.91	90.00
SM	38.54	31.57	100.00
CPL	39.79	31.57	90.00
CM	30.21	24.78	80.00
P	40.21	33.08	95.00
SG	46.25	26.10	85.00
SB	43.54	33.08	90.00
SP	47.92	35.23	95.00
SGS	1.04	3.29	15.00
CP	55.00	27.47	85.00
CG	37.71	24.85	95.00

Table 33. Statistics of tuber weights taken 20 August 1973.

VARIABLE	MEAN	S.D.	RANGE
CB	0.26	0.23	0.80
SW	0.31	0.27	0.80
SM	0.47	0.44	1.30
CPL	0.35	0.34	1.30
CM	0.64	0.28	1.30
P	0.48	0.56	2.20
SG	0.48	0.55	1.70
SB	0.43	0.46	1.50
SP	0.36	0.37	1.20
SGS	1.48	0.67	2.60
CP	0.39	0.26	1.00
CG	0.55	0.45	1.80

FIELD EXPERIMENT - TREATMENTS

Table 34. Results of Duncan's New Multiple Range Test for CPB larvae count taken 12 July 1973.

p	2	3	4	5	6	7	8	9	10	11	12
.05 rp	2.84	2.99	3.08	3.15	3.20	3.25	3.28	3.31	3.33	3.35	3.37
Rp	4.80	5.05	5.21	5.32	5.41	5.49	5.54	5.59	5.63	5.66	5.70
SGS	CB	SG	CP	CM	SB	CG	CPL	SM	SP	P	SW
0.00	0.54	4.29	4.58	4.62	5.33	5.96	6.83	9.20	9.58	12.37	12.75

Table 35. Results of Duncan's New Multiple Range Test for CPB larvae count taken 19 July 1973.

p	2	3	4	5	6	7	8	9	10	11	12
.05 rp	2.84	2.99	3.08	3.15	3.20	3.25	3.28	3.31	3.33	3.35	3.37
Rp	17.44	18.36	18.91	19.34	19.65	19.96	20.14	20.32	20.45	20.60	20.69
SGS	CB	CM	CP	CPL	SW	SB	P	SM	SP	SG	CG
0.00	3.00	9.17	10.17	14.58	15.75	15.92	17.66	19.63	19.83	25.42	40.13

FIELD EXPERIMENT - TREATMENTS

Table 36. Results of Duncan's New Multiple Range Test for CPB larvae count taken 26 July 1973.

p	2	3	4	5	6	7	8	9	10	11	12
.05 rp	2.84	2.99	3.08	3.15	3.20	3.25	3.28	3.31	3.33	3.35	3.37
Rp	18.09	19.05	19.62	20.07	20.38	20.70	20.89	21.09	21.21	21.34	21.47
SGS	CB	CP	CM	SW	SP	SM	P	CPL	SB	SG	CG
0.71	1.21	9.50	15.71	16.42	16.71	18.50	19.63	19.83	25.79	31.25	44.42

Table 37. Results of Duncan's New Multiple Range Test for CPB larvae count taken 3 August 1973.

p	2	3	4	5	6	7	8	9	10	11	12
.05 rp	2.84	2.99	3.08	3.15	3.20	3.25	3.28	3.31	3.33	3.35	3.37
Rp	15.25	16.06	16.54	16.92	17.18	17.45	17.61	17.77	17.88	17.99	18.10
CB	CP	SGS	CM	SM	SG	SP	CG	SW	P	CPL	SB
0.29	3.63	3.75	5.00	13.71	18.13	19.17	21.17	21.25	21.63	21.67	24.38

FIELD EXPERIMENT - TREATMENTS

Table 38. Results of Duncan's New Multiple Range Test for CPB larvae count taken 9 August 1973.

p	2	3	4	5	6	7	8	9	10	11	12
.05 rp	2.84	2.99	3.08	3.15	3.20	3.25	3.28	3.31	3.33	3.35	3.37
Rp	15.25	16.06	16.54	16.92	17.18	17.45	17.61	17.77	17.88	17.99	18.10
CB	CP	CM	SGS	CPL	CG	SG	SM	P	SW	SP	SB
0.13	1.38	2.50	4.83	14.42	16.42	18.79	20.00	25.08	25.08	25.38	29.75

Table 39. Results of Duncan's New Multiple Range Test for CPB adults taken 26 July 1973.

p	2	3	4	5	6	7	8	9	10	11	12
.05 rp	2.84	2.99	3.08	3.15	3.20	3.25	3.28	3.31	3.33	3.35	3.37
Rp	2.36	2.48	2.56	2.62	2.66	2.70	2.72	2.75	2.76	2.78	2.80
SGS	CG	CB	CP	CM	P	SB	SM	CPL	SP	SW	SG
0.38	1.00	1.75	1.79	1.96	2.08	2.88	3.00	4.54	4.79	4.88	4.92

FIELD EXPERIMENT - TREATMENTS

Table 40. Results of Duncan's New Multiple Range Test for CPB adult count taken 9 August 1973.

p	2	3	4	5	6	7	8	9	10	11	12
.05 rp	2.84	2.99	3.08	3.15	3.20	3.25	3.28	3.31	3.33	3.35	3.37
Rp	8.66	9.12	9.39	9.61	9.76	9.91	10.00	10.10	10.16	10.22	10.28
CB	CP	CM	SW	P	SB	SP	SG	SGS	CPL	SM	CG
2.13	2.79	3.71	8.21	9.96	11.92	12.83	14.71	14.83	16.54	16.58	20.42

Table 41. Results of Duncan's New Multiple Range Test for potato flea beetle damage assessment taken 2 July 1973.

p	2	3	4	5	6	7	8	9	10	11	12
.05 rp	2.84	2.99	3.08	3.15	3.20	3.25	3.28	3.31	3.33	3.35	3.37
Rp	4.03	4.25	4.37	4.47	4.54	4.62	4.66	4.70	4.73	4.76	4.79
SGS	CPL	SG	SM	CM	CG	SW	SB	CP	P	SP	CB
9.27	12.90	14.04	14.22	14.50	14.91	15.02	15.20	15.89	16.84	17.38	18.85

FIELD EXPERIMENT - TREATMENTS

Table 42. Results of Duncan's New Multiple Range Test for plant damage assessment taken 12 July 1973.

p	2	3	4	5	6	7		8	9	10	11	12
.05 rp	2.84	2.99	3.08	3.15	3.20	3.25		3.28	3.31	3.33	3.35	3.37
Rp	18.69	19.67	20.27	20.73	21.06	21.39		21.58	21.78	21.91	22.04	22.18
SGS	CG	CB	CM		P	CPL	SG	CP	SB	SP	SW	SM
2.08	4.38	8.13	10.42		22.08	22.71	24.17	29.38	30.42	31.25	32.92	33.13

Table 43. Results of Duncan's New Multiple Range Test for plant damage assessment taken 20 July 1973

p	2	3	4	5	6	7	8	9	10	11	12
.05 rp	2.84	2.99	3.08	3.15	3.20	3.25	3.28	3.31	3.33	3.35	3.37
Rp	18.32	19.29	19.87	20.32	20.64	20.96	21.16	21.35	21.48	21.61	21.74
SGS	CG	CB	CM	CPL	SG	SB	P	SM	CP	SW	SP
1.46	13.13	14.17	14.79	30.00	33.54	34.38	36.04	36.25	36.67	41.46	44.79

Table 44. Results of Duncan's New Multiple Range Text for plant damage assessment taken 31 July 1973.

p	2	3	4	5	6	7	8	9	10	11	12
.05 rp	2.84	2.99	3.08	3.15	3.20	3.25	3.28	3.31	3.33	3.35	3.37
Rp	20.62	21.71	22.36	22.87	23.23	23.60	23.81	24.03	24.18	24.32	24.47
SGS	CM	CG	SM	CPL	P	SB	CB	SG	SW	SP	CP
1.04	30.21	37.71	38.54	39.79	40.21	43.54	43.75	46.25	47.29	47.92	55.00

Table 45. Results of Duncan's New Multiple Range Test for tuber weights taken 20 August 1973.

p	2	3	4	5	6	7	8	9	10	11	12
.05 rp	2.84	2.99	3.08	3.15	3.20	3.25	3.28	3.31	3.33	3.35	3.37
Rp	0.27	0.28	0.29	0.30	0.30	0.31	0.31	0.31	0.31	0.32	0.32
CB	SW	CPL	SP	CP	SB	SM	SG	P	CG	CM	SGS
0.26	0.31	0.35	0.36	0.39	0.43	0.47	0.48	0.48	0.55	0.64	1.48

FIELD EXPERIMENT - TREATMENTS

Table 46. Results of Duncan's New Multiple Range Test for CPB larvae count taken 12 July 1973.

p	2	3	4	5	6	7	8	9	10	11	12
.01 rp	3.78	3.94	4.05	4.14	4.19	4.25	4.29	4.33	4.36	4.39	4.41
Rp	6.39	6.66	6.85	7.00	7.08	7.18	7.25	7.32	7.37	7.42	7.45
SGS	CB	SG	CP	CM	SB	CG	CPL	SM	SP	P	SW
0.00	0.54	4.29	4.58	4.62	5.33	5.96	6.83	9.20	9.58	12.37	12.75

Table 47. Results of Duncan's New Multiple Range Test for CPB larvae count taken 19 July 1973.

p	2	3	4	5	6	7	8	9	10	11	12
.01 rp	3.78	3.94	4.05	4.14	4.19	4.25	4.29	4.33	4.36	4.39	4.41
Rp	23.21	24.19	24.87	25.42	25.73	26.10	26.34	26.59	26.77	26.96	27.08
SGS	CB	CM	CP	CPL	SW	SB	P	SM	SP	SG	CG
0.00	3.00	9.17	10.17	14.58	15.75	15.92	17.66	19.63	19.83	25.42	40.13

FIELD EXPERIMENT - TREATMENTS

Table 48. Results of Duncan's New Multiple Range Test for CPB larvae count taken 26 July 1973.

p	2	3	4	5	6	7	8	9	10	11	12
.01 rp	3.78	3.94	4.05	4.14	4.19	4.25	4.29	4.33	4.36	4.39	4.41
Rp	24.08	25.10	25.80	26.37	26.69	27.07	27.33	27.58	27.77	27.96	28.09
SGS	CB	CP	CM	SW	SP	SM	P	CPL	SB	SG	CG
0.71	1.21	9.50	15.71	16.42	16.71	18.50	19.63	19.83	25.79	31.25	44.42

Table 49. Results of Duncan's New Multiple Range Test for CPB larvae count taken 3 August 1973.

p	2	3	4	5	6	7	8	9	10	11	12
.01 rp	3.78	3.94	4.05	4.14	4.19	4.25	4.29	4.33	4.36	4.39	4.41
Rp	20.30	21.16	21.75	22.23	22.50	22.82	23.04	23.25	23.41	23.57	23.68
CB	CP	SGS	CM	SM	SG	SP	CG	SW	P	CPL	SB
0.29	3.63	3.75	5.00	13.71	18.13	19.17	21.17	21.25	21.63	21.67	24.38

FIELD EXPERIMENT - TREATMENTS

Table 50. Results of Duncan's New Multiple Range Test for CPB larvae count taken 9 August 1973.

p	2	3	4	5	6	7	8	9	10	11	12
.01 rp	3.78	3.94	4.05	4.14	4.19	4.25	4.29	4.33	4.36	4.39	4.41
Rp	20.30	21.16	21.75	22.23	22.50	22.82	23.04	23.25	23.41	23.57	23.68
CB	CP	CM	SGS	CPL	CG	SG	SM	P	SW	SP	SB
0.13	1.38	2.50	4.83	14.42	16.42	18.79	20.00	25.08	25.08	25.38	29.75

Table 51. Results of Duncan's New Multiple Test for CPB adult count taken 26 July 1973.

p	2	3	4	5	6	7	8	9	10	11	12
.01 rp	3.78	3.94	4.05	4.14	4.19	4.25	4.29	4.33	4.36	4.39	4.41
Rp	3.14	3.27	3.36	3.44	3.48	3.53	3.56	3.59	3.62	3.64	3.66
SGS	CG	CB	CP	CM	P	SB	SM	CPL	SP	SW	SG
0.38	1.00	1.75	1.79	1.96	2.08	2.88	3.00	4.54	4.79	4.88	4.92

FIELD EXPERIMENT - TREATMENTS

Table 52. Results of Duncan's New Multiple Range Test for CPB adult count taken 9 August 1973.

p	2	3	4	5	6	7	8	9	10	11	12
.01 rp	3.78	3.94	4.05	4.14	4.19	4.25	4.29	4.33	4.36	4.39	4.41
Rp	11.53	12.02	12.35	12.63	12.78	12.96	13.09	13.21	13.30	13.39	13.45
CB	CP	CM	SW	P	SB	SP	SG	SGS	CPL	SM	CG
2.13	2.79	3.71	8.21	9.96	11.92	12.83	14.71	14.83	16.54	16.58	20.42

Table 53. Results of Duncan's New Multiple Range Test for flea beetle damage assessment take 2 July 1973.

p	2	3	4	5	6	7	8	9	10	11	12
.01 rp	3.78	3.94	4.05	4.14	4.19	4.25	4.29	4.33	4.36	4.39	4.41
Rp	5.37	5.60	5.75	5.88	5.95	6.04	6.09	6.15	6.19	6.23	6.26
SGS	CPL	SG	SM	CM	CG	SW	SB	CP	P	SP	CB
9.27	12.90	14.04	14.22	14.50	14.91	15.02	15.20	15.89	16.84	17.38	18.85

FIELD EXPERIMENT - TREATMENTS

Table 54. Results of Duncan's New Multiple Range Test for plant damage assessment taken 12 July 1973.

	p	2	3	4	5	6	7	8	9	10	11	12
.01	rp	3.78	3.94	4.05	4.14	4.19	4.25	4.29	4.33	4.36	4.39	4.41
	Rp	24.87	25.93	26.65	27.24	27.57	27.97	28.23	28.49	28.69	28.89	29.02

SGS	CG	CB	CM	P	CPL	SG	CP	SB	SP	SW	SM
2.08	4.38	8.13	10.42	22.08	22.71	24.17	29.38	30.42	31.25	32.92	33.13

FIELD EXPERIMENT - TREATMENTS

Table 55. Results of Duncan's New Multiple Range Test for plant damage taken 20 July 1973.

r	2	3	4	5	6	7	8	9	10	11	12
.01 rp	3.78	3.94	4.05	4.14	4.19	4.25	4.29	4.33	4.36	4.39	4.41
Rp	24.38	25.41	26.12	26.70	27.03	27.41	27.67	27.93	28.12	28.32	28.45
SGS	CG	CB	CM	CPL	SG	SB	P	SM	CP	SW	SP
1.46	13.13	14.17	14.79	30.00	33.54	34.38	36.04	36.25	36.67	41.46	44.79

Table 56. Results of Duncan's New Multiple Range Test for plant damage taken 31 July 1973.

p	2	3	4	5	6	7	8	9	10	11	12
.01 rp	3.78	3.94	4.05	4.14	4.19	4.25	4.29	4.33	4.36	4.39	4.41
Rp	27.44	28.60	29.40	30.06	30.42	30.86	31.15	31.44	31.65	31.87	32.02
SGS	CM	CG	SM	CPL	P	SB	CB	SG	SW	SP	CP
1.04	30.21	37.71	38.54	39.79	40.21	43.54	43.75	46.25	47.29	47.92	55.00

FIELD EXPERIMENT - BLOCKS

Table 57. Results of Duncan's New Multiple Range Test for CPB larvae count taken 12 July 1973.

	p	2	3	4	5	6
.05	rp	2.78	2.93	3.03	3.10	3.16
	Rp	2.95	3.11	3.21	3.29	3.35

1	2	4	3	5	6
3.60	6.00	6.31	6.38	7.56	8.19

Table 58. Results of Duncan's New Multiple Range Test for CPB larvae count taken 3 August 1973.

	p	2	3	4	5	6
.05	rp	2.78	2.93	3.03	3.10	3.16
	Rp	7.31	7.71	7.97	8.15	8.31

2	5	3	6	4	1
7.77	12.29	13.75	14.10	18.69	20.27

FIELD EXPERIMENT - BLOCKS

Table 59. Results of Duncan's New Multiple Range Test for CPB larvae count taken 9 August 1973.

	p	2	3	4	5	6
.05	rp	2.78	2.93	3.03	3.10	3.16
	Rp	7.40	7.79	8.06	8.25	8.41

6	5	3	4	2	1
6.33	10.27	12.27	12.69	18.83	31.48

Table 60. Results of Duncan's New Multiple Range Test for CPB adult count taken 3 August 1973.

	p	2	3	4	5	6
.05	rp	2.78	2.93	3.03	3.10	3.16
	Rp	3.36	3.55	3.67	3.75	3.82

1	6	4	5	2	3
8.35	9.73	10.04	12.66	12.81	13.88

FIELD EXPERIMENT - BLOCKS

Table 61. Results of Duncan's New Multiple Range Test for CPB adult count taken 9 August 1973.

	p	2	3	4	5	6
.05	rp	2.78	2.93	3.03	3.10	3.16
	Rp	3.53	3.72	3.85	3.94	4.01

1	6	3	2	4	5
8.33	9.38	11.21	12.54	12.92	12.94

FIELD EXPERIMENT - BLOCKS

Table 62. Results of Duncan's New Multiple Range Test for potato flea beetle damage assessment taken 2 July 1973.

p	2	3	4	5	6
.05 rp	2.84	2.99	3.08	3.15	3.20
Rp	2.84	2.99	3.08	3.15	3.20

4	2	5	1	3	6
10.07	14.08	14.88	16.01	17.10	17.37

FIELD EXPERIMENT - BLOCKS

Table 63. Results of Duncan's New Multiple Range Test for plant damage assessment taken 12 July 1973.

	p	2	3	4	5	6
.05	rp	2.78	2.93	3.03	3.10	3.16
	Rp	9.34	9.85	10.18	10.42	10.62
1		4	2	3	5	6
13.44		17.19	17.92	21.46	21.77	31.67

Table 64. Results of Duncan's New Multiple Range Test for plant damage assessment taken 20 July 1973.

	p	2	3	4	5	6
.05	rp	2.78	2.93	3.03	3.10	3.16
	Rp	8.87	9.35	9.67	9.89	10.08
1		2	4	3	5	6
14.79		23.44	25.73	28.65	29.48	44.17

FIELD EXPERIMENT -BLOCKS

Table 65. Results of Duncan's New Multiple Range Test for plant damage assessment taken 3 August 1973.

	p	2	3	4	5	6
.05	rp	2.78	2.93	3.03	3.10	3.16
	Rp	8.81	9.29	9.61	9.83	10.02
1		2	4	3	5	6
20.94		28.96	38.65	38.75	44.69	63.65

Table 66. Results of Duncan's New Multiple Range Test for tuber weights taken 20 August 1973.

	p	2	3	4	5	6
.05	rp	2.78	2.93	3.03	3.10	3.16
	Rp	0.13	0.14	0.14	0.15	0.15
	6	5	3	2	4	1
	0.21	0.34	0.49	0.51	0.56	0.97

FIELD EXPERIMENT - BLOCKS

Table 67. Results of Duncan's New Multiple Range Test for CPB larvae count taken 9 August 1973.

	p	2	3	4	5	6
.01	rp	3.65	3.81	3.91	3.99	4.05
	Rp	9.71	10.14	10.40	10.61	10.77
	6	5	3	4	2	1
	6.33	10.27	12.27	12.69	18.82	31.48

Table 68. Results of Duncan's New Multiple Range Test for CPB adult count taken 3 August 1973.

	p	2	3	4	5	6
.01	rp	3.65	3.81	3.91	3.99	4.05
	Rp	4.42	4.61	4.73	4.83	4.90
	1	6	4	5	2	3
	8.35	9.73	10.04	12.66	12.81	13.88

FIELD EXPERIMENT - BLOCKS

Table 69. Results of Duncan's New Multiple Range Test for flea beetle damage assessment taken 2 July 1973.

	p	2	3	4	5	6
.01	rp	3.77	3.93	4.04	4.13	4.18
	Rp	3.77	3.93	4.04	4.13	4.18

4	2	5	1	3	6
10.07	14.08	14.88	16.01	17.10	17.37

FIELD EXPERIMENT - BLOCKS

Table 70. Results of Duncan's New Multiple Range Test for plant damage assessment taken 12 July 1973.

	p	2	3	4	5	6
.01	rp	3.65	3.81	3.91	3.99	4.05
	Rp	12.26	12.80	13.14	13.41	13.61

1	4	2	3	5	6
13.44	17.19	17.92	21.46	21.77	31.67

Table 71. Results of Duncan's New Multiple Range Test for plant damage assessment taken 20 July 1973.

	p	2	3	4	5	6
.01	rp	3.65	3.81	3.91	3.99	4.05
	Rp	11.64	12.15	12.47	12.73	12.92

1	2	4	3	5	6
14.79	23.44	25.73	28.65	29.48	44.17

FIELD EXPERIMENT - BLOCKS

Table 72. Results of Duncan's New Multiple Range Test for plant damage assessment taken 31 July 1973

	p	2	3	4	5	6
.01	rp	3.65	3.81	3.91	3.99	4.05
	Rp	11.57	12.08	12.40	12.65	12.84

1	2	4	3	5	6
20.94	28.96	38.65	38.75	44.69	63.65

Table 73. Results of Duncan's New Multiple Range Test for tuber weights taken 20 August 1973.

	p	2	3	4	5	6
.01	rp	3.65	3.81	3.91	3.99	4.05
	Rp	0.18	0.19	0.20	0.20	0.20

6	5	3	2	4	1
0.21	0.34	0.49	0.51	0.56	0.98

GREENHOUSE EXPERIMENT

Table 74. Analysis of variance for CPB larvae damage assessment.

ANOVA

Source	df	SS	MS	Observed F
Total	35	16872.22		
B	5	2480.56	496.11	1.14
T	5	3530.55	706.11	1.63
BT(Error)	25	10861.11	434.44	

Table 75. Analysis of variance for CPB adult damage assessment.

ANOVA

Source	df	SS	MS	Observed F
Total	35	19807.64		
B	5	1986.81	397.36	0.67
T	5	3045.14	609.03	1.03
BT(Error)	25	14775.69	591.03	

GREENHOUSE EXPERIMENT

Table 76. Analysis of variance for potato flea beetle damage assessment.

ANOVA

Source	df	SS	MS	Observed F
Total	35	24389.00		
B	5	7690.00	1538.00	3.68*
T	5	6245.67	1249.13	2.99*
BT(Error)	25	10453.33	418.13	

GREENHOUSE EXPERIMENT - BLOCKS

Table 77. Results of Duncan's New Multiple Range Test for potato flea beetle damage assessment.

	p	2	3	4	5	6
.05	rp	2.92	3.07	3.15	3.22	3.28
	Rp	24.38	25.64	26.30	26.89	27.39
	6	4	5	1	2	3
	6.00	7.50	11.33	18.00	35.33	44.83

SUPPLEMENTARY LITERATURE CITED

Amonkar, S. V. and E. L. Reeves. 1970. Mosquito control with active principle of garlic, Allium sativum. J. Econ. Entomol. 63:1172-5.

________ and A. Banerji. 1971. Isolation and Characterization of larvicidal principle of garlic. Science. 174:1343-4.

Andrews, D. J. 1974. Responses of sorghum varieties to intercropping. Exp. Agric. 10:57-63.

Briggs, R. and C. M. Harrison. 1953. The effect of various companion crops on the establishment of alfalfa. Mich. Agric. Exp. Sta. Quart. Bull. 36:130-7.

Bula, R. J., D. Smith and E. E. Miller. 1954. Measurements of light beneath a small grain companion crop as related to legume establishment. Bot. Gaz. 115:271-8.

Carson, Rachel. 1970. Silent Spring. Fawcett Publications, Inc. Greenwich, Ct. 304 p.

Clark, V. A. 1908. Observations on nurse crops for alfalfa. Ariz. Agric. Exp. Sta. Bull. 57:284-7.

Collister, E.H. and H. H. Kramer. 1952. The effect of oat variety on the stand and development of red clover. Agron. J. 44:385.

Cooper, C. S. and H. Ferguson. 1964. Influence of a barley companion crop upon root distribution of alfalfa, birdsfoot trefoil, and orchardgrass. Agron. J. 56:63-6.

Dethier, V. G. 1941. Chemical factors determining the choice of food plants by Papilio larvae. Am. Nat. 75:61-73.

Enyi, B. A. C. 1973. Effects of intercropping maize or sorghum with cowpeas, pigeon peas or beans. Exp. Agric. 9:83-90.

Hawkins, A., M. G. Savos, W. Melnick and C. J. Gilgut. 1973. 1973 Potato Pest Control Guide for Commercial Growers in Connecticut and Massachusetts. Coop. Ext. Serv.Univ. Conn. Univ. Mass. 8 p.

Hughes, H. D. and F. S. Wilkins. 1935. A study of certain of the factors influencing the success of plantings of the small-seeded legumes. Iowa Agric. Exp. Sta. Ann. Rpt. 118-9.

Hukusima, S. 1959. Studies on the insect association in a crop field. XVI. Effect of cultural practices on the structures of insect communities in potato fields, with special reference to the cause bringing about the difference of community structures in field of potato alone and intercropped with corn. Jap. J. Appl. Entomol. Zool. 3:72-9. (Original not read. Abstract in Biological Abstracts. 1960. Vol. 35).

Hunter, B. T. 1971. Gardening without Poisons. Houghton Mifflin Co. Boston, Ma. 318 p.

Klebesadel, L. J. and D. Smith. 1959. Light and soil moisture beneath several companion crops as related to the establishment of alfalfa and red clover. Bot. Gaz. 121:39-46.

________ 1960. Effects of harvesting an oat companion crop at four stages of maturity on the yield of oats, on light near the soil surface, on soil moisture, and on the establishment of alfalfa. Agron. J. 52:627-30.

Kust, C. A. 1968. Herbicides or oat companion crops for alfalfa establishment and forage yields. Agron. J. 60:151-4.

Lai, T. M. and K. Lawton. 1962. Root competition for fertilizer phosphorus as affected by intercropping. Soil Sci. Soc. Am. Proc. 26:58-62.

Lawrence, T. 1967. Effect of a wheat companion crop on the seed yield of Russian wild ryegrass. Can. J. Plant Sci. 47:585-92.

________ 1970. Effect of a wheat companion crop on the seed and dry matter yield of crested wheatgrass. Can. J. Plant Sci. 50:81-6.

Lewis, T. 1965. The effect of an artificial windbreak on distribution of aphids in a lettuce crop. Ann. Appl. Biol. 55:513-8.

________ 1966. An analysis of components of wind affecting the accumulation of flying insects near artificial windbreaks. Ann. Appl. Biol. 58:365-70.

________ 1969 a. The distribution of flying insects near a low hedgerow. J. Appl. Ecol. 6:443-52.

________ 1969 b. The diversity of the insect fauna in a hedgerow and neighbouring fields. J. Appl. Ecol. 6:453-8.

Lochhead, W. 1919. Class Book of Economic Entomology. P. Blakiston's Son & Co. Philadelphia, Pa. 436 p.

Lower, R. L. 1972. Effect of surrounding cultivar when screening cucumber for resistance to cucumber beetle and pickleworm. J. Am. Soc. Hortic. Sci. 97:616-8.

Lueck, A. G., V. G. Sprague and R.J. Garber. 1949. The effects of a companion crop and depth of planting on the establishment of smooth bromegrass, Bromus inermis, Leyss. Agron. J. 41:137-40.

Mays, D. A. and E. M. Evans. 1972. Effects of variety, seeding rate, companion species, and cutting schedule on crownvetch yield. Agron. J. 64:283-5.

McGowan, A. A. and W. A. Williams. 1971. Growth of subterranean clover established with a cereal companion crop. Agron. J. 63:643-6.

Metcalf, C. L. and W. P. Flint. 1928. Destructive and Useful Insects Their Habits and Control. McGraw-Hill Book Co., Inc. New York, N. Y. 918 p.

________ 1939. Destructive and Useful Insects Their Habits and Control (Second Ed.). McGraw-Hill Book Co. Inc. New York, N. Y. 981 p.

________ R. L. Metcalf. 1951. Destructive and Useful Insects Their Habits and Control (Third Ed.). McGraw-Hill Book Co., Inc. New York, N. Y. 1071 p.

Metzger, F. W. and D. H. Grant. 1932. Repellency to the Japanese beetle of extracts made from plants immune to attack. U. S. Dept. Agric. Tech. Bull. 299:1-22.

Moline, W. J. and L. R. Robison. 1971. Effect of Herbicides and seeding rates on the production of alfalfa. Agron. J. 63:614-6.

National Academy of Sciences. 1969. Insect-Pest Management and Control. National Academy of Sciences. Washington, D. C. 508 p.

Nelson, C. J., A. R. Schmid and C. H. Cuykendall. 1965. Performance of berseem clover (Trifolium alexandrinum L.) as a companion crop. Agron. J. 57:537-9.

Pendleton, J. W. and G. H. Dungan. 1953. Effect of different oat spacings on growth and yield of oats and red clover. Agron. J. 45:442-4.

Peters, R. A. 1961. Legume establishment as related to the presence or absence of an oat companion crop. Agron. J. 53:195-8.

Pritchett, W. L. and L. B. Nelson. 1951. The effect of light intensity on the growth characteristics of alfalfa and bromegrass. Agron. J. 43:172-7.

Sanderson, E. D. 1912. Insect Pests of Farm, Garden and Orchard. John Wiley and Sons. New York, N. Y. 684 p.

________ and L. M. Peairs. 1921. Insect Pests of Farm, Garden and Orchard. John Wiley and Sons, Inc. New York, N. Y. 707 p.

Schmid, A. R. and R. Behrens. 1972. Herbicides vs oat companion crops for alfalfa establishment. Agron. J. 64:157-9.

Scholl, J. M. and D. W. Staniforth. 1957. Establishment of birdsfoot trefoil as influenced by competition from weeds and companion crops. Agron. J. 49:432-5.

Sempers, F. W. 1894. Injurious Insects and the Use of Insecticides. W. Atlee Burpee and Co. Philadelphia, Pa. 216 p.

Shands, W. A. and B. L. Landis. 1970. Controlling Potato Insects. Farmers' Bull. 2168. U. S. Dept. Agric. 15 p.

Smith, D., H. J. Lowe, A. M. Strommen and G. N. Brooks. 1954. Establishment of legumes as influenced by the rate of sowing the oat companion crop. Agron. J. 46:449-51.

van Emden, H. F. 1962. A preliminary study of insect numbers in field and hedgerow. Entomol. Mon. Mag. 98:255-9.

________ 1965. The effect of uncultivated land on the distribution of cabbage aphid (*Brevicoryne brassicae*) on an adjacent crop. J. Appl. Ecol. 2:171-96.

Varma, M. P. and M. S. Subba Rao Kanke. 1969. Selection of intercrops for cotton in India. Exp. Agric. 5:223-30.

Wolfenbarger, D. O. 1940. Relative prevalence of potato flea beetle injuries in fields adjoining uncultivated areas. Ann. Entomol. Soc. Am. 33:391-4.